THE ACIDIC PRECIPITATION IN ONTARIO STUDY

(APIOS)

AN OVERVIEW:

THE CUMULATIVE WET/DRY DEPOSITION NETWORK

Report # ARB-15-82-ARSP

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Ontario
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1. INTRODUCTION

The phenomenon of acidic precipitation has been recognized as a regional, provincial and international-scale perturbation of the environment. The Air Resources Branch (ARB) of the Ministry of the Environment (MOE) has established two monitoring networks which operate under the auspices of the Acidic Precipitation in Ontario Study (APIOS). The APIOS Cumulative Wet/Dry Deposition Network and the APIOS Event Wet/Dry Deposition Network have been designed to collect data so that a quantification of both wet and dry deposition patterns can be ascertained.

Although the primary concern for both networks is the measurement of deposition, they differ accordingly by the time resolution of their sampling periods. The event (used interchangeably with the term daily) network collects precipitation and air filter samples on a daily basis to investigate the characteristics and to determine the origin of pollutants deposited in these events, i.e. short-term wet and dry deposition patterns. The cumulative network monitors on a 28-day cycle (on a monthly basis from the network's inception in September, 1980 to January 5, 1982), collecting precipitation, dry fall and air filter samples to measure long-term wet and dry deposition distributions.

Details of the event network are described elsewhere in "The Acidic Precipitaton in Ontario Study (APIOS). An Overview: The Event Wet/Dry Deposition Network" (Chan et al., 1982). This document is available from the Air Resources Branch. No further discussion of this network will be given in this document.

The cumulative deposition network to be presented herein will be described according to its two components under the headings "Cumulative Wet Deposition Network" and "Cumulative Dry Deposition Network" respectively. The exceptions to this format are found in the sections entitled 'Network Design' and 'Network Siting Criteria and Sampling Locations', since a cumulative sampling site must fulfill the same requirements for both wet and dry deposition collection.

2. NETWORK OBJECTIVES

2.1 Cumulative Wet Deposition Network:

The objectives of this network are twofold:

1) To study the chemical composition of cumulative precipitation samples (collected on a 28-day cycle) within the province.

2) To determine the long-term wet deposition distributions of various chemical parameters (both temporally and spatially) across the province.

2.2 Cumulative Dry Deposition Network:

The objectives of this network are also two-fold:

1) To determine the ambient concentration of airborne acid-related pollutants on a cumulative (28-day) basis.

2) To determine dryfall rates of these pollutants on a cumulative basis by measurement of direct deposition onto the dry bag collector and to infer dry deposition by using airborne concentrations (obtained by low-volume air filtration) with appropriate deposition velocity values in the relationship:

deposition rate = deposition velocity x concentration.

Based on these estimates, the long-term dry deposition distributions of various chemical parameters (both temporally and spatially) across the province can be derived.

3. NETWORK DESIGN

The design of the cumulative network is based on historical data from the Canadian Network for Sampling Acid Precipitation (CANSAP) and on the results of MOE long-range transport computer modelling. The cumulative network was designed to satisfy the following objectives:

1) to provide long-term (seasonal/annual) data to determine deposition fields of acid, sulfur and nitrogen species and trace metals, based on cumulative (28-day) collections,
2) to provide for placement of samplers on spatial scales varying from local to regional to provincial,
3) to give special emphasis to sampling in areas of highest expected and known deposition and/or high susceptibility to acidic deposition.

The sampling program is conducted in five of the Ministry of the Environment's regions (regional offices in parentheses): the Southwestern region (London), encompassing the West-Central region; the Central region (Dorset); the Southeastern region (Kingston); the Northeastern region (Sudbury); the Northwestern region (Thunder Bay). Because the steepest gradients in deposition exist in Southern Ontario, the density of samplers is highest there. The number of low-volume air samplers in each region is slightly less than those of the wet/dry collectors because of smaller spatial variability in air quality data.

4. NETWORK SITING CRITERIA AND SAMPLING LOCATIONS

Based on the design criteria outlined in the previous section, all MOE regions were inspected for suitable sampling sites. Determining the actual locations involved fulfilling both the aforementioned spatial requirements as well as site-specific requirements. The latter requisites are described in detail here.

The overriding consideration in site selection is the prevention of sample contamination. This is accomplished by locating sampling sites away from local area sources of pollution so that the samplers are regionally representative. In addition, the sampling instruments must be located at a site which has little or no potential for affecting the integrity of the collected samples, i.e. they must be clear of obstructions, and other site-specific sources of contamination nearby must be minimized. The following list summarizes the many sources of contamination that could affect the chemical integrity of samples, both wet and dry:

* urban areas (industrial activity, vehicle emissions, human activity)
* airports
* highways
* trees (obstructions, rain splash, organic debris, throughfall)
* buildings (obstructions, rain splash, emissions)
* unpaved roads (spray, salt, sand, airborne dust, vehicle emissions, snow ploughing, snow blowing)
* sewage treatment plants and aeration lagoons
* cultivated fields and orchards (herbicide and pesticide spraying, fertilizer emissions, airborne dust, organic debris)
* overhead wires
* oil or gas wells
* parking lots
* ground cover (rock, loose soil)
* marshes (emissions, insects)
* gravel pits
* salt or sand piles
* gardens

In addition to the minimizing of sample contamination, siting criteria must also incorporate factors which affect the logistics and operation of samplers. The major considerations are:

* site characteristics (ground cover should be grassy and flat, and as open and cleared as possible)
* avoidance of obstructions (adhere to a minimum 2.5 times of distance of sampler from obstruction to height-of-obstruction)
* surrounding vegetation (windbreaks approximately 200 m away improve sampler catch efficiency)
* accessibility (easy access required but must be removed from roads)
* topography (locations near hills and depressions should be avoided)
* electrical supply
* safety (must be free from vandalism)
* personnel to regularly maintain sampler and collect samples.

To aid in a comprehensive evaluation of a site, a site criteria checklist (Appendix 1) is used. Acceptance of a site for sampling depends upon the meeting of most (if not all) of the site characteristics. To indicate the importance of proper siting in the APIOS program, site characteristics generally over-ride all other factors.

To date, thirty-six sites have been chosen for wet/dry automated samplers by applying the APIOS network siting criteria. Low-volume air samplers are co-located at twenty-three of these sites. Some of the sites are located on Ministry of the Environment property while others are on private property. The actual sampling locations are shown in Figure 1 and listed in Table 1.

5. INSTRUMENTATION

5.1 Cumulative Wet Deposition Network:

Each cumulative deposition site is instrumented with an automated deposition collector and a standard APIOS precipitation storage gauge to serve as a primary standard of the total precipitation occurred during a particular 28-day period. The instrument used is a Sangamo Type A Deposition Collector (presently being manufactured by M.I.C. Company). The standard manufacturer's instrument has been modified by Air Resources Branch to eliminate or reduce the effect of several problems. A description of the instrument and its major modifications follows.

The principal features of the Sangamo Type A sampler are:

1) sensor grids (extending out from the body of the collector) for the detection of precipitation,

2) high-density polyethylene collection vessels, with a sufficiently large surface area ($\sim 324\ cm^2$) and

3) a moveable hood (when precipitation comes in contact with the sensor grids, the circuitry of the grids becomes closed, activating the instrument to expose its 'wet' collection vessel and cover its 'dry' side).

The major modifications to the Sangamo Type A collector are as follows:

1) A pliable silicon gasket is attached to the stainless-steel underside of the moveable hood. Its purpose is to form a tight

seal between the top of the collection vessel and the underside of the hood to minimize evaporative loss of the sample. In addition, the gasket stops contaminants from entering the sample through gaps between the top of the vessel and the underside of the hood. The gasket is also very important for preventing metals contamination of the sample. Recirculation of sample water can occur as it evaporates inside the bucket, condenses on the underside of the hood, and ultimately drips back into the sample. With no gasket present, the condensate can leach metals from the steel surface and drip them into the bucket. Laboratory testing of this gasket indicates that there is negligible contribution of any chemical constituents of interest from the gasket to the sample.

2) The use of disposable food-grade polyethylene/nylon laminate-type bags (polyethylene bags were used before November, 1982) inserted into collector's buckets to serve as collection containers is a regular feature of the cumulative network. The use of bags as a collection medium is very desirable, primarily due to the reduction of potential contamination and sample handling associated with sample transfers and the elimination of cleaning of collection vessels. Desorption of chemical constitutes from the bag surface has been found to be minimal. Although the bags present pristine environment for sampling precipitation, laboratory analyses have shown that long-term adsorption exists for the trace metals Fe, Al, Cr and Zn which can be recovered by mild nitric acid leaching.

3) A knife edge collar is attached to the top of the precipitation bucket after the bag is inserted. This clamps the bag in place and gives the sample container a very distinct, narrow edge. This, in turn, reduces rain drop splash and prevents the pick-up of particulates on the edge. The efficient seal between the hood gasket and knife edge serves to minimize evaporation.

4) To improve the efficiency of snow collection, namely by eliminating the blow-out of already collected snow from the collection vessel under high wind conditions, a long bucket and bag for winter precipitation collection has been implemented. Wind tunnel testing at the University of Toronto (Haasz and Solomon, 1980) indicated that the use of a 1 m length collection vessel provides approximately a 4:1 height to diameter ratio, which would optimize the vessel's aerodynamic properties and is sufficient to minimize the snow blow-out effect. To accommodate this longer container, the bottom of the 'wet' side of the Sangamo is cut out and an adjustable support base is attached to the standpost.

5) Standardization of the sensitivity and opening/closing response time of the precipitation collector has occurred so that all samplers across the province react alike to the same type of precipitation. Sensitivity is tested by special sensor grids outfitted with a 220 K resistor. The timing control has been altered on the collector's integrated circuit so that opening and closing of the hood is set at a two-minute delay.

Calculation of the total amount of wet deposition requires a knowledge of the sample chemistry and the total amount of precipitation that falls over the sampling period. Because the efficiency of the sampling instrumentation is less than perfect, the amount of precipitation collected in the sampler is not the true amount. Since most sampling sites do not have manpower on-site to operate standard precipitation gauges on a daily basis, each sampler is then accompanied by an APIOS precipitation storage gauge. This instrument accumulates precipitation over the sampling period and a depth measurement is taken when the sample is collected. To ensure the depth measurement is as accurate as possible, a capping layer of oil is placed in the gauge during the 'summertime' collection period (May to October) to prevent evaporation of the collected precipitation. In the 'wintertime' collection period (November to April) a 60%/40% mixture of methanol/ethylene glycol is placed in the unit to melt the collected snow.

5.2 Cumulative Dry Deposition Network:

In the beginning of the network operation, measurement of dry deposition was in the form of collection of dry fall samples in the dry side bucket of the Sangamo deposition collector. Similar to the wet deposition collection, polyethylene bags were used. In the summer of 1981, in an attempt to better assess the measurement of dry deposition on a cumulative basis, the APIOS program instituted the use of a low-volume air filtration system. It was felt that this system would augment and, at the same time, provide data for comparison with those of the dry bag measurements. At present, both methodologies are in use for dry deposition estimates. The "dry side" bucket of the Sangamo collector discussed in the previous section is used for dryfall measurments. The low-volume air filtration equipment is discussed below.

The long-term ambient air sampler used in the APIOS network is a Metrex Instrument Ltd AS-2 Low-Volume Air Sampler. The basic features of the instrument are i) a vacuum system controlled by a Gast heavy-duty diaphragm pump, in which the flow rate is controlled by a Dwyer Instruments VFA23 rotameter, ii) a temperature-compensated dry gas meter facilitates accurate monitoring of the flow and, iii) digital counters record associated total volumetric flow and operating time.

The pumping system is used in conjunction with a modified 'Swinnex' two-stage, 47 mm polypropylene filter pack mounted on a 2 m tower. The filter pack samples for 28 days (commencing at 0800h local time) at a flow rate of 2.0 litres per minute. Vacuum Jayon tubing connects the filter pack (mounted on a filter pack support plate and enclosed in a protective housing) to the pumping system. The system is oriented toward the dry-side of the co-located Sangamo collector.

Within each filter pack there are three types of filters, each type specific for chemical parameters of interest. The upstream filter is a 47 mm Whatman 40 cellulose filter, which is analysed for water-soluble sulfate, nitrate, ammonium, chloride, sodium, magnesium, calcium, potassium, and the trace metals aluminum, manganese, iron, copper, nickel, lead, zinc, cadmium and vanadium, total acidity and free hydrogen ion concentration. The Whatman 40 filter is followed by a Membrana (Ghia Division) Corporation 47 mm, 1 um Nylon filter, used for the selective adsorption of vapour phase nitric acid. Both filters are loaded in the upstream stage of the filter pack and are in direct contact. The final type of filter used is 50 mm Whatman 41 cellulose filter impregnated with a potassium carbonate/glycerol solution. This impregnating solution selectively absorbs sulfur dioxide. Two of these filters are loaded in the downstream stage and are also in direct contact.

6. SAMPLE COLLECTION AND HANDLING TECHNIQUES

6.1 Cumulative Wet Deposition Network:

Previously collection of cumulative deposition samples was made on the last-working-day-of-the-month. As of January 5, 1982 the APIOS program began collection of samples on Tuesdays (at 0800 hours local time) every 28 days. On the collection Tuesday, a structured sampling protocol is carried out by an on-site operator. This includes: i) removal of the collected sample, ii) cleaning of the instrument, iii) deployment of new sample bags, iv) check of instrument performance, v) measurement of storage gauge and vi) recording of observations. A brief synopsis of this protocol is given below.

On changeover dates, the site operator at each station activates the sensor and then stops the hood midway by switching the sampler off. The knife edge collar is then removed from the bucket. After donning a pair of sterilized polyethylene gloves, the sample is removed by grasping the portion of the bag above the bucket between the thumb and forefinger and lifting upward. As the bag is removed, it is squeezed at the point where the bag folds over the edge of the bucket. Excess air is purged out of the bag, then sealed with a twist tie.

Prior to the installation of a new bag, the instrument is thoroughly cleansed in an effort to minimize the potential of contamination. This requires the operator to wipe the sensor grids and, most importantly, the silicon gasket and retaining collar with ethanol-soaked Kimwipes. A thorough rinsing with deionized-distilled water follows. The parts are then dried with Kimwipes.

To install a new bag, it must be fully expanded and then pushed into the bucket until it nears the bottom. The top of the bag is slid over the top of the bucket and then pulled down until it extends 4-5 inches down the outside of the bucket (i.e. that portion that has been handled). The retaining collar is then secured around the bag at the top of the bucket. At this point of the procedure, a new set of gloves must be put on. The operator must reach inside the bucket and flatten the bag against the inside and the top of the bucket. The operator would then repeat the procedure for the 'dry' bag.

After both wet and dry bags have been changed, a brief check of the operation of the instrument is made. Once turned on, a check to see that the hood moves from the centre of the buckets to cover the wet side (if the sensor grids are dry) is done. Other precautions taken include ensuring that a tight seal between the gasket and the wet side collection vessel exists, activating the sensor grids to check that the hood moves to cover the dry collection vessel, checking the time taken for the hood to return to cover the wet side vessel (the response time should be approximately 2 minutes) and finally, ensuring that the sensor grids are warm to the touch.

The remaining task of the operator is to take an accurate precipitation depth measurement of the precipitation storage gauge. To calculate the amount of rainfall that fell during the collection period, the gauge must be measured at the beginning and end of the collection period, with the difference between measurements representing the fallen precipitation. In the wintertime collection period changes in density of the storage gauge methanol/ethylene glycol mixture must be accounted for, thus it becomes necessary for the operator to record the mixture's temperature at time of measurement.

As part of the APIOS Quality Assurance Program, all pertinent information regarding the sample itself is noted on an operator field sheet that accompanies each sample or in instrument and operator log-books on site. If inconsistencies in sampler performance or serious problems affecting the sample's integrity exist, the APIOS technician responsible for the site is notified for corrective action.

Samples collected are picked up monthly from the on-site operators by APIOS technicians responsible for the samplers in their area (samples from the more remote sites in Northeastern and Northwestern Ontario are shipped to the nearest regional MOE office). The samples are transported in coolers to a regional MOE office. The samples are visually inspected for organic debris, particulates and leaks, weighed for the determination of sample volume, properly sealed with a heat sealer, and then labelled. The samples are packed in coolers and shipped by courier service to the Laboratory Services Branch of the Ministry in Toronto, arriving the following day still cooled. In Toronto, the samples are logged in and stored at 4°C before chemical analysis.

6.2 Cumulative Dry Deposition Network:

The protocol used for the dry bag samples collection is similar to that described for the wet samples and therefore will not be repeated here.

The filter pack samples of this network are obtained at the same time as the wet and dry bag collection, i.e. on designated dates every 28 days at 0800 hours local time. The sampling protocol is as follows: prior to an upcoming sampling changeover date, an unexposed filter pack is loaded with Whatman 40, Nylon and K_2CO_3-glycerol impregnated Whatman 41 filters, sealed in a 'Whirl-Pak' polyethylene bag, then either shipped or taken to the sampling site. At the site, the low-volume sampler is shut-off and the associated flow rate, flow volume and total time sampled are recorded on operator field sheets. The exposed filter pack is covered with a new 'Whirl-Pak' bag, twisted off the threaded nylon support plate and the bag sealed. The reverse of this procedure is carried out to mount the new unexposed filter pack. The digital counters on the low-volume sampler are reset to zero and the instrument is switched on to commence sampling.

Upon receipt at the regional MOE office, the filter packs are unloaded. The Whatman 40 filter is laid flat and stored in a small Petri container, while the nylon and Whatman 41 filters are stored in 'Whirl-Pak' bags. All filters are labelled and then submitted to the Laboratory Services Branch for chemical analyses.

7. CHEMICAL ANALYSES

7.1 Cumulative Wet Deposition Network:

All cumulative precipitation samples are analyzed for the following parameters: volume, conductivity, pH, total acidity, $SO_4^{=}$, $N\text{-}NO_3^{-}$, $N\text{-}NH_4^{+}$, Cl^{-}, Ca^{++}, Mg^{++}, Na^{+}, K^{+}, N-TKN (total Kjeldahl nitrogen), TP (total phosphorus), Zn, Fe, Ni, Cu, Pb, Al, Cd, Mn and V. The methods of analysis are given in Table 2.

7.2 Cumulative Dry Deposition Network:

Similar analyses and associated analytical methods are employed on the dry collection bags as for the wet deposition samples. These bags are first filled with one litre of deionized-distilled water, left to sit for 24 hours, then set in an ultrasonic bath for 15 minutes before the sample is analyzed. After the aliquot is analyzed for conductivity, pH, total acidity, $SO_4^{=}$, $N\text{-}NO_3^{-}$, $N\text{-}NH_4^{+}$, Cl^{-}, Ca^{++}, Mg^{++}, Na^{+}, K^{+}, Na^{+}, K^{+}, N-TKN and TP, the remaining portion is analyzed for the water-soluble trace metals, consisting of Zn, Fe, Ni, Cu, Pb, Al, Cd, Mn and V. Finally, after having been emptied, the dry bag is leached with a 5% HNO_3 solution, to allow for the determination of Zn, Fe, Ni, Cu, Pb, Al, Cd, Mn and V that may have adsorbed on the bag walls.

The individual filters are analyzed for both water quality and inorganic trace constituents. The Whatman 40 filters are analyzed firstly for the metals Al, Mn, Fe, Cu, Ni, Pb, Zn, Cd and V by X-ray fluorescence (XRF). These filters then undergo a deionized-distilled water extraction and are analyzed for $SO_4^{=}$, $N\text{-}NO_3^{-}$, $N\text{-}NH_4^{+}$, Cl^{-}, Ca^{++}, Mg^{++}, Na^{+} and K^{+}. From the nylon filter, $N\text{-}HNO_3$ (as nitrate) is determined and from the impregnated Whatman 41 filters, SO_2 (as $SO_4^{=}$) is determined. Methods of extraction and analysis are given in Table 3.

8. DATA HANDLING AND ANALYSIS

8.1 Cumulative Wet Deposition Network:

The reporting of chemical analysis is structured such that laboratory-approved data are entered from the Laboratory Information System (LIS) into the Ministry's Sample Information System (SIS) data base. A particular submission's supporting field data are merged with the corresponding chemical data. Before the results are finalized, the data are screened according primarily to chemical balance testing, exceedance of range tests, and Dixon-ratio statistical testing (comparison of chemical values for designated geographical regions over the same time interval). Analysis of the data involves the calculation of cumulative wet deposition rates as the product of pollutant concentration times the true precipitation depth.

8.2 Cumulative Dry Deposition Network:

Data from this network undergo the same transfer and screening procedures as the wet deposition data.

Analysis of the dry bag data is similar to that of the wet deposition data. Dry deposition rates are also calculated as the product of pollutant air concentration (for air filter samples) and published values of deposition velocity.

REFERENCES

Chan, W.H., D.B. Orr and R.J. Vet. The Acidic Precipitation in Ontario Study- "An Overview: The Event Wet/Dry Deposition Network", Air Resources Branch Report No. ARB-11-82-ARSP, July 1982.

Haasz, A.A. and D. Solomon. Wind Tunnel Simulation Studies of Snow Collector Gauges, Institute for Aerospace Studies, Univesity of Toronto, May 1980.

STATIONS

1	COLCHESTER
2	MERLIN
3	PORT STANLEY
4	WILKESPORT
5	ALVINSTON
6	HURON PARK
7	WATERLOO
8	PALMERSTON
9	SHALLOW LAKE
10	MILTON
11	UXBRIDGE
12	COLDWATER
13	CAMPBELLFORD
14	KALADAR
15	SMITH'S FALLS
16	DALHOUSIE MILLS
17	GOLDEN LAKE
18	WILBERFORCE
19	WHITNEY
20	DORSET
21	MCKELLAR
22	MATTAWA
23	KILLARNEY
24	BEAR ISLAND
25	GOGAMA
26	RAMSEY
27	MOOSEAM
28	ATTAWAPISKAT
29	WINISK
30	WASINA
31	ORION
32	QUETICO CENTRE
33	LAC LA CROIX
34	E.L.A.
35	EAR FALLS
36	PICKLE LAKE

FIGURE 1

LOCATION OF APIOS CUMULATIVE WET/DRY DEPOSITION SITES

TABLE 1

APIOS CUMULATIVE WET/DRY DEPOSITION NETWORK SITE DESCRIPTIONS

MOE REGION	STATION NAME	STATION NUMBER	INSTRUMENTATION	ELEVATION (m above MSL)	LATITUDE (North)	LONGITUDE (West)	UTM GRID CO-ORDINATES (Northing)	(Easting)
Southwestern	Colchester	1041	Sangamo/Low-Volume Air	183	41°59'15"	82°55'41"	4650000	340300
	Merlin	1051	Sangamo	191	42°14'47"	82°13'30"	4676400	398950
	Pt. Stanley	1061	Sangamo/Low-Volume Air	213	42°40'22"	81°09'55"	4724050	486700
	Wilkesport	1071	Sangamo/Low-Volume Air	183	42°42'11"	82°21'13"	4728350	389150
	Alvinston	1081	Sangamo	221	42°49'36"	81°50'04"	4942000	431550
	Shallow Lake	1091	Sangamo/Low-Volume Air	229	44°34'54"	81°05'24"	4936200	492850
	Palmerston	1101	Sangamo/Low-Volume Air	389	43°48'19"	80°54'12"	4850050	507750
	Huron Park	1191	Sangamo	250	43°17'28"	81°30'03"	4793000	459350
	Waterloo	2021	Sangamo	343	43°28'39"	80°35'09"	4813750	533500
Central	Dorset	3011	Sangamo/Low-Volume Air	320	45°13'26"	78°55'52"	5009650	662400
	Milton	3051	Sangamo/Low-Volume Air	221	43°31'05"	79°55'54"	4818600	586350
	Uxbridge	3061	Sangamo/Low-Volume Air	244	44°12'46"	79°12'38"	4896800	643000
	Wilberforce	3071	Sangamo	396	45°00'54"	78°12'58"	4988150	719400
	Campbellford	3081	Sangamo/Low-Volume Air	175	44°17'28"	77°47'33"	4907600	277150
	Coldwater	3101	Sangamo	280	44°37'31"	79°32'08"	4942200	615900
Southeastern	Kaladar	4051	Sangamo/Low-Volume Air	244	44°41'31"	77°09'18"	4950800	329250
	Smith's Falls	4061	Sangamo/Low-Volume Air	122	44°56'41"	75°57'48"	4977100	423950
	Dalhousie Mills	4071	Sangamo/Low-Volume Air	69	45°19'00"	74°28'13"	5018100	541550
	Golden Lake	4081	Sangamo/Low-Volume Air	160	45°36'48"	77°12'03"	5053200	328400
Northeastern	McKellar	5011	Sangamo/Low-Volume Air	244	45°30'57"	79°55'19"	5040600	583950
	Killarney	5021	Sangamo/Low-Volume Air	183	45°59'26"	81°29'18"	5092900	462200
	Mattawa	5031	Sangamo/Low-Volume Air	198	46°16'45"	78°49'19"	5127150	667800
	Bear Island	5041	Sangamo	305	46°58'22"	80°04'40"	5202400	570350
	Ramsey	5051	Sangamo	427	47°26'33"	82°20'14"	5254900	399200
	Gowganda	5061	Sangamo/Low-Volume Air	343	47°39'04"	80°46'32"	5277300	516600
	Moonbeam	5071	Sangamo/Low-Volume Air	244	49°19'16"	82°08'46"	5463600	416650
	Attawapiskat	5081	Sangamo/Low-Volume Air	9	52°56'00"	82°24'00"	NA	NA
	Whitney	5091	Sangamo	412	45°32'21"	78°15'35"	5045950	713950
Northwestern	Dorion	6011	Sangamo/Low-Volume Air	244	48°50'33"	88°36'45"	5410800	382150
	Naidna	6021	Sangamo/Low-Volume Air	320	50°10'38"	86°42'40"	5558150	520950
	Ear Falls	6031	Sangamo/Low-Volume Air	350	50°38'31"	93°13'13"	5609800	484150
	Pickle Lake	6041	Sangamo/Low-Volume Air	360	51°27'41"	90°12'04"	5704800	694550
	Lac la Croix	6061	Sangamo	368	48°21'14"	92°12'32"	5355900	558400
	Quetico Centre	6071	Sangamo	420	48°44'24"	91°12'08"	5399750	632100
	E.L.A.	6091	Sangamo	123	49°39'22"	93°43'28"	5500950	447350
	Winisk	6101	Sangamo	9	55°12'00"	85°08'00"	NA	NA

TABLE 2

APIOS CUMULATIVE WET/DRY SAMPLE LABORATORY ANALYSES

PARAMETER	ANALYSIS METHOD	DETECTION LIMIT ($mg\ l^{-1}$)
pH (for H_f* determination)	Radiometer	0.01 pH units
Total Acidity (for H_t^+ determination)	NaOH titration to pH 8.3; results presented as mg $CaCO_3\ l^{-1}$	0.01
	Gran titration: NaOH titration to a series of inflection points; results presented as ug l^{-1} as H^+	0.01
Conductivity	Radiometer	0.30 umhos cm^{-1}
$SO_4^=$	Ion Chromatography	0.05
$N\text{-}NO_3^-$	Ion Chromatography	0.01
Cl^-	Ion Chromatography	0.01
$N\text{-}NH_4^+$	Automated phenate-hypochlorite colorimetry	0.002
Ca^{++}	Flame Atomic Absorption	0.01
Na^+	Flame Atomic Absorption	0.005
K^+	Flame Atomic Absorption	0.005
Mg^{++}	Flame Atomic Absorption	0.005
N-TKN	Automated phenate-hypochlorite colorimetry	0.0045
TP	Ammonium molybdate-ascorbic acid colorimetry	0.004
Zn	Flame Absorption	0.002
Fe	Flameless Atomic Absorption	0.001
Ni	Flameless Atomic Absorption	0.001
Cu	Flameless Atomic Absorption	0.001
Pb	Flameless Atomic Absorption	0.001
Al	Flameless Atomic Absorption	0.005
Cd	Flameless Atomic Absorption	0.0001
Mn	Inductively Coupled Plasma	0.001
V	Flameless Atomic Absorption	0.002

* H_f - Free hydrogen ion concentration
+ H_t^f - Total hydrogen ion concentration

TABLE 3

APIOS CUMULATIVE LOW-VOLUME AIR FILTER LABORATORY ANALYSES

PARAMETER		FILTER TYPE	EXTRACTION METHOD	ANALYSIS METHOD	DETECTION LIMIT ($mg\ l^{-1}$)
i)	Zn	Whatman 40	None	X-ray Fluorescence	0.002
ii)	Fe	Whatman 40	None	X-ray Fluorescence	0.001
iii)	Ni	Whatman 40	None	X-ray Fluorescence	0.001
iv)	Cu	Whatman 40	None	X-ray Fluorescence	0.001
v)	Pb	Whatman 40	None	X-ray Fluorescence	0.001
vi)	Al	Whatman 40	None	X-ray Fluorescence	0.005
vii)	Cd	Whatman 40	None	X-ray Fluorescence	0.0001
viii)	Mn	Whatman 40	None	X-ray Fluorescence	0.001
ix)	V	Whatman 40	None	X-ray Fluorescence	0.002
x)	$SO_4^=$	Whatman 40	Same as above	Ion Chromatography	0.05
xi)	$N\text{-}NO_3$	Whatman 40	Same as above	Ion Chromatography	0.01
xii)	$N\text{-}NH_4$	Whatman 40	Same as above	Automated phenate-hypochlorite colorimetry	0.01
xiii)	$N\text{-}HNO_3$	Nylon	15 minute ultrasonic bath in 25 ml 3×10^{-3} N NaOH	Ion Chromatography (as NO_3^-)	0.01
xiv)	SO_2	Whatman 41	30 minute shaking in 50 ml 0.05% (v/v) hydrogen peroxide; followed by 15 minute shaking in 25 ml hydrogen peroxide; followed by making up to 100 ml with hydrogen peroxide	Ion Chromatography (as $SO_4^=$)	0.05

APPENDIX 1

Site Criteria Checklist

1. Open area?

2. Obstructions?
   - buildings?
   - trees?
   - poles, towers?

3. Distance from obstructions (2.5 x height)?

4. Roads -do they exist?
   - how far away?
   - surface?
   - how cleaned in winter?

5. Fields nearby?
   - cultivated?
   - sprayed?
   - fertilized?
   - crop?
   - future plans?

6. Local sources nearby?
   - town sources nearby?
   - smokestack?
   - oil or gas wells?
   - industry?
   - gravel pits?
   - salt or sand piles?
   - parking lots?
   - airport?
   - marshes?
   - fertilizer plants?
   - sewage lagoons

7. Overhead wires?

8. Buildings nearby?
   - how far?
   - power available?
   - heating method?
   - people?

9. Power
   - amperage of service?
   - access?
   - special requirements?

10. Trench
   - type of soil?
   - obstructions (eg. roads, tress, buildings)?
   - length of trench?

11. Ground cover?
   - type?
   - consistent?
   - future plans?

12. Wind break?

13. Topography?
   - level or hilly?
   - site location?

14. Safety?
   - vandalism?
   - fence requried?

15. Access?
   - to location?
   - to sampler?
   - winter?

16. Land owner?
    - name and address?
    - cooperative?
    - full address of site?
    - own power supply?
    - remuneration OK?
    - future increases in instrumentation OK?

17. Operator(s)?
    - land owner willing?
    - suggested alternative operators?
    - how far from site?
    - special requirements (eg. weekends)?
    - name and address?
    - vehicle available?
    - suitability (smart, willing, interested, time)?
    - permission to access sampler?
    - commitment?
    - require refrigerator?
    - remuneration satisfactory?

18. Authorization?
    - who?
    - name and address?
    - special requirements?

19. Electrician and/or trencher?
    - suggested name and phone number?